International Journal of Mathematics and Physical Sciences Research ISSN 2348-5736 (Online)
Vol. 7, Issue 2, pp: (41-52), Month: October 2019 - March 2020, Available at: www.researchpublish.com

Mathematical Model of the dynamics of Rumor Spreading with Psychological Effect in Emergency Event

[1*]Mohammed Fori, [2]Samuel Musa, [3]Ibrahim Yakubu Mshalia, [4]Salihu Saleh

[1,4]Department of Mathematics, College of Education Waka Biu, PMB 1508, Waka-Biu, Borno State, Nigeria.

[2]Department of Mathematics, Modibbo Adama University of Technology Yola, PMB 2076, Yola, Adamawa State, Nigeria.

[3]Department of Biology, College of Education Waka Biu, PMB 1508, Waka-Biu, Borno State, Nigeria.

∗ **Corresponding author:** forinice@yahoo.com, +2348063240226, +2348083168432

Abstract: **In this paper, a deterministic mathematical model is formulated using epidemiological model approach composed by mutually exclusive spreader compartments of ISR (ignorant – spreaders – stiflers), which provides excellent explanations of the "psychological" effect with rumor spreading in emergency event. We showed that as time evolves rumor will seize spreading when $R_o < 1$ or persists if $R_o > 1$ by studying the stability of the rumor-free equilibrium and the rumor-endemic equilibrium. Finally, numerical simulation was performed in order to validate the analytical result and recommendations are explored in the case study of rumors propagated on unknown disease attacking students of College of Education Waka Biu upon arriving from Biology field trip that took place at Yankari game reserve in august 2019.**

Keywords: **Rumor spreading, Psychological effect, Reproduction number, Rumour free equilibrium, Rumor endemic equilibriums.**

1. INTRODUCTION

Rumor represents unproven exposition about or interpretations of news, events, or problems that are of public interest (Zhao, Wang & Huang, 2015). It is a circulated story, report or statement without fact to confirm its truth; and it spread like a virus, once a rumor is transmitted to an individual, an outbreak of events happens within a short period of time. Traditionally, rumors are propagated by the word of mouth, but with the emergence of the internet, rumor spread by instant messengers, emails or publishing blogging and social media that provide faster speed of transmission (Zho *at. el*, 2012). Once a rumor spread the truth is at risk of being distorted in the public sphere, rumor is thus possible to spread more quickly and widely through online social media compared to the traditional off line social communities.

Allport and Postman (1947) defined rumors as propositions of faith on specific (or current) topics that pass from person to person, usually by word of mouth, without any evidence of their truth. Although rumors are usually communicated from person to person by word of mouth, the media have a key role in their spread. For Allport and Postman (1947) the basic characteristics of rumors are:

- ✓ they are transmitted by word of mouth;
- ✓ they provide information about people, events and conditions;
- ✓ they express and meet the emotional needs of the community.

A crucial aspect in the definition of rumors is the emphasis given to their characteristics:

- ✓ disclosure (word of mouth, which is amplified by newspapers and media);
- ✓ content (news that is in the public domain, to be distinguished from private and trivial matters);
- ✓ listening (rumor spreads to the community because it responds to the emotional needs).

2. RUMOR MODEL

Scholars look for rumor – spreading laws through establishing rumor – spreading models. The fundamental law of rumor states that the strength of rumor is directly proportional to the significance of the subject towards the individual or public interest and to the uncertainty of the evidence at hand. A modified theory views rumor – mongering as a way of handling anxieties and uncertainties during chaotic times by creating and passing on stories, and attempting to provide and explanation for behavior and address confusion (Rosnow , 2001) as in (Rabajante & Umali, 2011). Specifically, rumors take place when no clear link exists between people and the correct information, causing ambiguity (Bordia and Difonzo, 2004). When people fail to find a plausible answer to their queries, they begin to interpret the situation and make use of the information at hand to come up with stories. Also, belief in a rumor depends on the degree of suggestibility and credulity of the rumor mongers involved. At the initial stage, most people do not have much information about the event, and spreaders could gain much satisfaction from telling the rumors; it was a major motive power for the spreading of news. In 2014, Abdullahi, Auwal and Abbas explained that, the more people knew about the rumor, the lower spreaders' grades and levels of personnel commitment are. Furthermore, rumors expired because people grow weary of an issue and stop talking or thinking about it.

According to psychoanalysis, Allport and Postman (1947) supported the idea that a rumor can respond to a state of uncertainty through the production of a response, and that this can have a cathartic effect. Robert Knapp, a student of Allport, collected and categorized rumors, and divided them in three categories based on their content:

- ✓ rumors of impossible dreams ('pipe-dream rumors'), which reflect public wishes and expected results;
- ✓ ghost rumors and rumors based on fear ('bogie-man or fear rumors'), which reflected popular fears and anxieties;
- ✓ rumors that lead to disagreement ('wedge-driving rumors'), which are intended to undermine alliances and relationships. Knapp concluded that negative rumors expand more easily than positive rumors.

Jung (1959) proposed a classification of rumors based primarily on their temporal duration. He distinguished the rumors as 'ordinary' and 'visionary'. For Jung (1959), visionary rumors have a universal symbolic value and they live a long time. This kind of rumor that expresses chronic anxiety is detectable in the archetypal images and the collective fears about the situation of the world, or in the universal desire for a supernatural power to redeem. Other authors, such as Festinger (1957) and Prasad (1935), argued instead that anxiety and fear are supported and supplied by rumors. In this interpretation, the function of rumors is precautionary and to alert against disaster, and they also have an adaptive function in relation to catastrophic events. In 2004, Prashant Bordia and Nicholas Di Fonzo published an article entitled Problem solving in social interactions on the internet: rumor as social cognition, where they stated that transmission of rumors is probably indicative of a "collective process of interpretation" (sense making). They reported also that in this process of collective problem solving, every rumor followed four stages of development:

- ✓ introduction of the rumor;
- ✓ spontaneous generation of opinions, from where discussions are created;
- ✓ resolution of the problem;
- ✓ loss of interest.

A rumor is analogous to a virus in the way that it spreads among individuals, so existing rumor – spread models are mostly inspired by the research results of infected disease models (Newman, 2012). The first rumor – spread mathematical model that has some properties in common with epidemic model was proposed by Delay and Kendall in 1965, called DK model (Delay & Kendall, 1964, 1965). Recently in 2019, Musa and Fori proposed a deterministic mathematical model which attempts to explain the propagation of rumor using epidemiological model approach. In their model, they explored the existence of the equilibria and analysed its stability. Consequently, it was shown that, the dynamics of rumor propagation spreading show similar behavior to that found in the dynamics of infectious diseases, except that the spread depends on the classes of spreaders. Different possible behaviors in the dynamics of rumor spreading were studied by Rene and Marco, (2017). In their study, they proposed a deterministic propagation of rumor model and detected relevant conditions, derived from local stability analysis of the rumor free equilibrium and rumor – endemic equilibrium. In 2016, Abdullahi, Abbas and Farouck proposed and analyzed a non linear mathematical model for rumor spreading in an epidemiological approach. They shown that nonmonotone and nonlinear incidence rate of the form $g(s) = KS/(1 + \alpha S^2)$, can be used to interpret the psychological effect with rumor spreading in emergency. Nekovee *et* *al.* (2007) regarded forgetting as a very important factor of rumor termination. Therefore, they introduced a forgetting mechanism into the SIR rumor spreading model and derived the mean – field equations in complex networks. They also confirm the existence of critical threshold for the rumor spreading in complex networks.

Since different people have different opinions for same event/information that have been spread on social media or verbally, this paper attempts to examine the level of rumor spreading of unknown disease in college of education Waka Biu which claimed lives of some students upon returning from field trip that took place at Yankari Game Reserve in Bauchi State using SIR epidemiological model approach. First, we refine this model and establish mean – field equations to describe the spreading process. Secondly, we derived and discuss the spreading threshold for steady – state spread of rumor, and confirm the existence of a critical threshold for the rumor spreading. Finally, we performed numerical simulations to examine the dynamics of the proposed model.

3. MODEL FORMULATION

Consider the differences between virus and rumor propagation, we should develop a specific propagation model for rumor spreading. Since different people have distinct opinions on same event, the class of the spreader is split into two sub classes; called spreader through media and spreader through verbal communication (figure 1).

In the model, we have four classes now as the class of spreader is divided into two, namely: $I(t)$ ignorant, $M(t)$ spreader through media, $V(t)$ spreader through verbal communication and stifler $R(t)$, as shown in figure 1. Those who belong to the ignorant class do not know anything about the rumor. Those who belongs to the spreader class, know the rumor and are actively spreading it on social media or verbally. Those who belong to the stifler class know the rumor and do not spread it. The total population size at time t is denoted by $N(t)$, with

$$N(t) = I(t) + M(t) + V(t) + R(t)$$

The model is built around the following assumptions:

i. When an ignorant meets a spreader through media or verbal communication, the ignorant turns into a new spreader though media/verbal communication with probability β_1/β_2.

ii. If a spreader through media meets a spreader through verbal communication, the spreader through media turn into a spreader through verbal communication with probability θ_1

iii. When spreader through verbal communication meets spreader through media, it turns into a spreader through media with probability θ_2

iv. The spreaders through media M and the spreaders through verbal communication V spontaneously become stiflers at the rate α_1 and α_2 respectively for losing interesting.

v. All recruited individuals are ignorant and death rates are equal. Also, spreading rumor through media and verbal communication are mutually exclusive event.

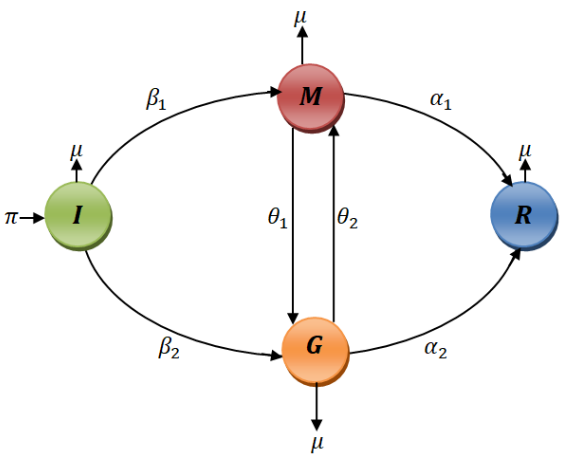

Figure1: Schematic diagram of the model

With respect to the above assumptions, the corresponding mathematical equations of the schematic diagram can be described by a system of Ordinary Differential Equation (ODEs) given below:

$$\left.\begin{aligned} \frac{dI}{dt} &= \pi - \beta_1 IM - \beta_2 IV - \mu I \\ \frac{dM}{dt} &= \beta_1 IM - \theta_1 VM + \theta_2 VM - \mu M - \alpha_1 M \\ \frac{dV}{dt} &= \beta_2 IM - \theta_2 VM + \theta_1 VM - \mu V - \alpha_2 V \\ \frac{dR}{dt} &= \alpha_1 M + \alpha_2 V - \mu R \end{aligned}\right\} \quad (1)$$

We assume that no transmission of rumor – class happens unless a spreader contact someone, since the ignorant that are not spreaders do not know anything about the rumor. When a spreader contacts an ignorant, the spreader transmits the rumor with psychological effect and the ignorant gets to know it. When two spreaders contact each other, both of them transmit the rumor at a constant frequency. After hearing it repeatedly, the spreader gets bored, gradually loses interest in it, and consequently become a stifler.

Table 1: Parameters of the model and their description

Parameter	Descriptions
π	The constant recruitment rate of the population
μ	The natural fade away rate to the ignorant, spreaders and stiflers
β_1	Effective contact rate between the ignorant and spreaders through media
β_2	Effective contact rate between the ignorant and spreaders through verbal communication
α_1	Forgetting rate of spreader through media
α_2	Forgetting rate of spreader through verbal communication
θ_1	Probability of spreader through media meeting a spreader through verbal communication
θ_2	Probability of spreader through media meeting a spreader through verbal communication

4. MODEL ANALYSIS

Since the model (1) monitor human populations, we assume all the variables and the associated parameters remain non negative at all time.

Summing the equations in (1), we obtain that the total population N satisfy the differential equation

$$\frac{dN}{dt} = \pi - \mu N \quad (2)$$

Whose solution is given by

$$N(t) = N_o e^{-\mu t} + \frac{(1 - e^{-\mu t})}{\mu} \quad (3)$$

Thus, we assume that the initial value is $N_o = I + M + V + R = \frac{\pi}{\mu}$ in order to have population of constant size $\left(i.e. I(t) + M(t) + V(t) + R(t) = N = \frac{\pi}{\mu}\right)$. Obviously, the state variables $I(t), M(t), V(t), R(t)$ remain in the sociologically meaningful set $\Omega = \left\{(I, M, V, R) \in \mathbb{R}_+^4 \,|\, 0 \leq I + M + V + R \leq \frac{\pi}{\mu}\right\}$

for $\left(I(0), M(0), V(0), R(0)\right) \in \mathbb{R}_+^4$, which is a positively invariant region. Hence it is sufficient to study the dynamics of the system (1) in Ω.

Rumor Free – Equilibrium State (RFE)

The RFE of the system (1) is attained when all the variables related to rumor spread are zero. Hence, the rumor – free equilibrium for the model is given by

$$E_o = \left(\frac{\pi}{\mu}, 0,0,0\right)$$

According to Hethcote (2000), the rumor free equilibrium is calculated as if rumor were never introduced into the system. From this, we can see that there should be no people in either the spreader classes or the stifler class.

Basic Reproduction Number $(\boldsymbol{R_o})$

One of the highly essential worry about any rumor is its ability to invade a population. The basic reproduction number R_o is 'one of the foremost and most valuable ideas that mathematical thinking has brought to epidemic theory' where control strategies are employed (Heesterbeek & dietz, 1996). It is defined as the number of newly spreaders produced by a typical spreader individual in a completely ignorant population (Musa & Fori, 2019). It is an important threshold parameter that determines whether or not, a rumor will spread through a given population.

We apply the next generation matrix technique by Dickmann, Heesterbeck and Roberts, (2009) to calculate the basic reproduction R_o, by considering the second and third equations of system (1), this is because at the spreading free steady state $I = R$. This means, the system has two spreading states M and V.

$$\left.\begin{aligned} \frac{dM}{dt} &= \beta_1 IM - \theta_1 VM + \theta_2 VM - \mu M - \alpha_1 M \\ \frac{dV}{dt} &= \beta_2 IM - \theta_2 VM + \theta_1 VM - \mu V - \alpha_2 V \end{aligned}\right\} \qquad (4)$$

Let matrix F represent the rate of appearance of new spreaders into the compartment and V represent rate of transfer into (out) of the compartment.

Thus,

$$F = \begin{pmatrix} \beta_1 I & 0 \\ 0 & \beta_2 I \end{pmatrix} \text{ and } V = \begin{pmatrix} \mu + \alpha_1 & 0 \\ 0 & \mu + \alpha_2 \end{pmatrix}$$

It follows that, the basic reproduction number of the model is given by

$$R_o = R_{o_m} + R_{o_v}$$

Where

$$R_{o_m} = \frac{\pi\beta_1}{\mu(\mu + \alpha_1)}$$

$$R_{o_v} = \frac{\pi\beta_2}{\mu(\mu + \alpha_2)}$$

5. STABILITY ANALYSIS

Local Stability Analysis of the Rumor Free Equilibrium

Theorem 1: The rumor free equilibrium point E_o is locally asymptotically stable if $R_o < 1$ and unstable if $R_o > 1$

Proof

The Jacobian of (1) at the equilibrium point $E_o = \left(\frac{\pi}{\mu}, 0,0,0\right)$ is

$$J_{E_o} = \begin{pmatrix} -\mu & -\frac{\pi\beta_1}{\mu} & -\frac{\pi\beta_2}{\mu} & 0 \\ 0 & \frac{\pi\beta_1}{\mu} - \mu - \alpha_1 & 0 & 0 \\ 0 & 0 & \frac{\pi\beta_2}{\mu} - \mu - \alpha_2 & 0 \\ 0 & \alpha_1 & \alpha_2 & -\mu \end{pmatrix} \quad (5)$$

Thus, the eigenvalues of (5) is obtained by using characteristic equation $|J_{E_o} - \lambda I| = 0$.

Hence,

$$\lambda_1 = -\mu$$

$$\lambda_2 = (R_{o_m} - 1)(\mu + \alpha_1)$$

$$\lambda_3 = (R_{o_v} - 1)(\mu + \alpha_2)$$

$$\lambda_4 = -\mu$$

Noting that $R_o = R_{o_m} + R_{o_v}$ and we observe that, all the eigenvalues of (5) has negative real parts when $R_o < 1$, hence the system stable. This indicate that, rumor can seize spreading when $R_o < 1$. Similarly, the eigenvalues of (5) has a positive real part if $R_o > 1$ that is, if $R_{o_m} > 1$ and $R_{o_v} > 1$, which shows there is no stability. Consequently, rumor will continue spreading and invade the population.

Existence of Rumor Media – Endemic Equilibrium

When rumor through media persists in a population (i.e. $M \neq 0$), the model equation (1) has an equilibrium point called rumor media endemic equilibrium point denoted by

$$E_1 = (I^{\sim}, M^{\sim}, V^{\sim}, R^{\sim})$$

Setting (1) to zero, we have

$$\left.\begin{aligned} &\pi - \beta_1 IM - \beta_2 IV - \mu I = 0 \\ &\beta_1 IM - \theta_1 VM + \theta_2 VM - \mu M - \alpha_1 M = 0 \\ &\beta_2 IM - \theta_2 VM + \theta_1 VM - \mu V - \alpha_2 V = 0 \\ &\alpha_1 + \alpha_2 V - \mu R = 0 \end{aligned}\right\} \quad (6)$$

Noting that, when $M \neq 0$ implies $V = 0$. Then from the second equation of (6), we obtained

$$I^{\sim} = \frac{\mu + \alpha_1}{\beta_1} \quad (7)$$

$$V^{\sim} = 0 \quad (8)$$

Using (7) and (8) in the first equation of (6), we have

$$M^{\sim} = (R_{o_m} - 1)\frac{\mu}{\beta_1} \quad (9)$$

Substituting (8) and (9) in the last equation of (6) yield

$$R^{\sim} = (R_{o_m} - 1)\frac{\alpha_1}{\beta_1} \quad (10)$$

Thus,

$$E_1 = (I^{\sim}, M^{\sim}, V^{\sim}, R^{\sim})$$

Local Stability of rumor media endemic equilibrium

We used the Jacobian Stability approach to prove the stability of the rumor media endemic equilibrium. The Jacobian of the (1), is given by

$$\begin{pmatrix} -\beta_1 M^{\approx} - \beta_1 V^{\approx} - \mu & -\beta_1 I^{\approx} & -\beta_2 I^{\approx} & 0 \\ \beta_1 M^{\approx} & \beta_1 I^{\approx} - \theta_1 V^{\approx} + \theta_2 V^{\approx} - \mu - \alpha_1 & -\theta_1 M^{\approx} + \theta_2 M^{\approx} & 0 \\ \beta_1 V^{\approx} & -\theta_2 V^{\approx} + \theta_1 V^{\approx} & \beta_2 I^{\approx} - \theta_2 M^{\approx} + \theta_1 M^{\approx} - \mu - \alpha_2 & 0 \\ 0 & \alpha_1 & \alpha_2 & -\mu \end{pmatrix} \quad (11)$$

Evaluating (11) at E_1, gives

$$\begin{pmatrix} -\beta_1\left(\frac{\pi}{\mu+\alpha_1} - \frac{\mu}{\beta_1}\right) - \mu & -\beta_1\left(\frac{\mu+\alpha_1}{\beta_1}\right) & -\beta_2\left(\frac{\mu+\alpha_1}{\beta_1}\right) & 0 \\ \beta_1\left(\frac{\pi}{\mu+\alpha_1} - \frac{\mu}{\beta_1}\right) & \beta_1\left(\frac{\mu+\alpha_1}{\beta_1}\right) - \mu - \alpha_1 & -\left(\frac{\pi}{\mu+\alpha_1} - \frac{\mu}{\beta_1}\right)(\theta_2 - \theta_1) & 0 \\ 0 & 0 & \beta_2\left(\frac{\mu+\alpha_1}{\beta_1}\right) - \left(\frac{\pi}{\mu+\alpha_1} - \frac{\mu}{\beta_1}\right)(\theta_2 - \theta_1) - \mu - \alpha_2 & 0 \\ 0 & \alpha_1 & \alpha_2 & -\mu \end{pmatrix} \quad (12)$$

Finding the eigenvalue of (12) using the characteristics equation $|J_{E_1} - \lambda I| = 0$. We have

$$\lambda_1 = -\beta_1 k_1 - \mu$$

$$\lambda_2 = 0$$

$$\lambda_3 = \beta_2 t_1 - k_1(\theta_2 - \theta_1) - \mu - \alpha_2$$

$$\lambda_4 = -\mu$$

Where $k_1 = \frac{\pi}{\mu+\alpha_1} - \frac{\mu}{\beta_1}$ and $t_1 = \frac{\mu+\alpha_1}{\beta_1}$

Since some of the eigenvalues are positive, it implies that rumor media endemic equilibrium is unstable.

Existence of Rumor Verbal – endemic equilibrium

When rumor through verbal communication persist in a population, the model equation has an equilibrium point called rumor verbal endemic denoted by

$$E_2 = (I^{\approx}, M^{\approx}, V^{\approx}, R^{\approx})$$

Since the spreading processes are mutually exclusive events, it implies when $M = 0, V \neq 0$ and vice versa. Equating (1) to zero, we have

$$\left.\begin{array}{l} \pi - \beta_1 IM - \beta_2 IV - \mu I = 0 \\ \beta_1 IM - \theta_1 VM + \theta_2 VM - \mu M - \alpha_1 M = 0 \\ \beta_2 IM - \theta_2 VM + \theta_1 VM - \mu V - \alpha_2 V = 0 \\ \alpha_1 + \alpha_2 V - \mu R = 0 \end{array}\right\} \quad (13)$$

In the present case, different spreaders informing people verbally are considered (i.e. $V > 1$), so the solution of the system of equations described by (13) is:

$$I^{\approx} = \frac{\mu + \alpha_2}{\beta_2} \quad (14)$$

$$M^{\approx} = 0 \quad (15)$$

$$V^{\approx} = \left(R_{o_v} - 1\right)\frac{\mu}{\beta_2} \quad (16)$$

$$R^{\approx} = \left(R_{o_v} - 1\right)\frac{\alpha_2}{\beta_2} \quad (17)$$

Thus

$E_2 = (I^{\approx}, M^{\approx}, V^{\approx}, R^{\approx})$

Local Stability of rumor verbal endemic equilibrium

The Jacobian of the (1), is given by

$$\begin{pmatrix} -\beta_1 M^{\approx} - \beta_1 V^{\approx} - \mu & -\beta_1 I^{\approx} & -\beta_2 I^{\approx} & 0 \\ \beta_1 M^{\approx} & \beta_1 I^{\approx} - \theta_1 V^{\approx} + \theta_2 V^{\approx} - \mu - \alpha_1 & -\theta_1 M^{\approx} + \theta_2 M^{\approx} & 0 \\ \beta_1 V^{\approx} & -\theta_2 V^{\approx} + \theta_1 V^{\approx} & \beta_2 I^{\approx} - \theta_2 M^{\approx} + \theta_1 M^{\approx} - \mu - \alpha_2 & 0 \\ 0 & \alpha_1 & \alpha_2 & -\mu \end{pmatrix} \quad (18)$$

Evaluating (18) at E_2

$$\begin{pmatrix} -\beta_1\left(\frac{\pi}{\mu+\alpha_2} - \frac{\mu}{\beta_2}\right) - \mu & -\beta_1\left(\frac{\mu+\alpha_2}{\beta_2}\right) & (\mu+\alpha_2) & 0 \\ 0 & \beta_1\left(\frac{\mu+\alpha_2}{\beta_2}\right) - \theta_1\left(\frac{\pi}{\mu+\alpha_2} - \frac{\mu}{\beta_2}\right) + \theta_2\left(\frac{\pi}{\mu+\alpha_2} - \frac{\mu}{\beta_2}\right) - \mu - \alpha_1 & 0 & 0 \\ \beta_1\left(\frac{\pi}{\mu+\alpha_2} - \frac{\mu}{\beta_2}\right) & -\theta_2\left(\frac{\pi}{\mu+\alpha_2} - \frac{\mu}{\beta_2}\right) + \theta_1\left(\frac{\pi}{\mu+\alpha_2} - \frac{\mu}{\beta_2}\right) & 0 & 0 \\ 0 & \alpha_1 & \alpha_2 & -\mu \end{pmatrix} \quad (19)$$

Finding the eigenvalue of (19) using the characteristics equation $|J_{E_2} - \lambda I| = 0$. We have

$$\lambda_1 = -\beta_2 k_2 - \mu$$

$$\lambda_2 = \beta_1 t_2 - k_2(\theta_1 - \theta_2) - \mu - \alpha_1$$

$$\lambda_3 = 0$$

$$\lambda_4 = -\mu$$

Where $k_2 = \frac{\pi}{\mu+\alpha_2} - \frac{\mu}{\beta_2}$ and $t_2 = \frac{\mu+\alpha_2}{\beta_2}$

Since of the eigenvalues are positive, it implies that rumor verbal endemic equilibrium is unstable

Corollary 1

System (1) has the following equilibrium:

i. If $R_o < 1$, system (1) has only a trivial equilibrium E_o

ii. If $R_o > 1$, system (1) has no a trivial equilibrium E_o

iii. If $R_{o_m} > 1$, $R_{o_v} < 1$, system (1) has a rumor verbal free equilibrium E_2

iv. If $R_{o_m} < 1$ and $R_{o_v} > 1$, system (1) has a rumor media free equilibrium E_1

6. NUMERICAL SOLUTION AND DISCUSSION OF RESULT

This section deals with the numerical studies of the developed model and discussion of the simulation result to confirm the analytical solution.

As students and staffs of college education Waka Biu, parent, relatives and friends are eager to know the cause of the disease that is attacking students which lead to the dead of two students and two photographers (ex students) after they have returned from the Biology field trip, multiple recipes of potential have flooded the mine of people. The rumor of Biology field trip of august 2019 in Biu local government of Borno state, which made two students and two photographers lose their lives, while some were hospitalized. This seriously impacted people's psychology and triggered a chain of disorders. The rumor messages suggesting from different opinions that it might be a demonic attack, food poisoning or unknown fever went viral over the week. Until the school management in collaboration with Borno state Ministry of Health quarantines all the students that were involved, carrying out investigations using blood sample and other methods in order to understand what has really happened so as to proffer solutions/suggestions by professional personnel. The essential point of the matter is that, in such an institution when the right public health messages and accurate awareness is not quickly spread by the relevant authorities, rumor, with it all knowing fangs would ride high on the crescendo of public ignorance.

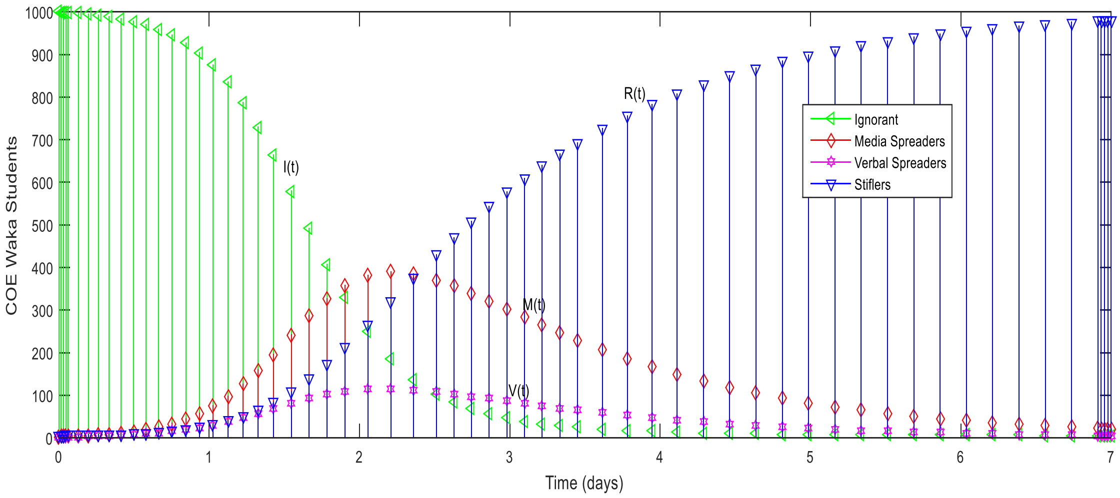

Figure 1: Variation of Ignorants, Spreaders and stiflers with respect to time

$\theta_1 = 0.02, \ \ \theta_1 = 0.01, \ \ \beta_1 = 0.8, \ \beta_2 = 0.8, \ \ \alpha_1 = 0.7, \ \alpha_2 = 0.75$

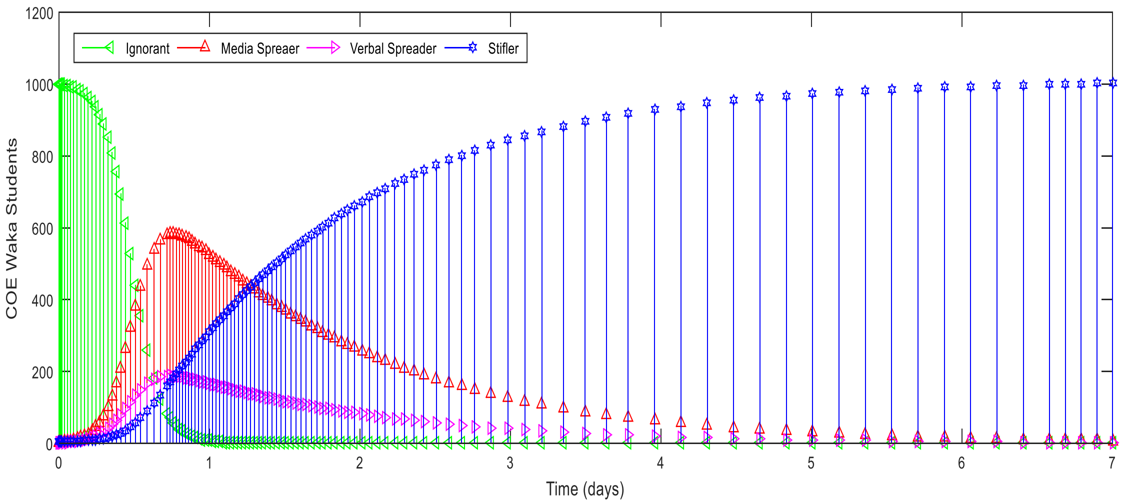

Figure 2: Variation of Ignorants, Spreaders and stiflers with respect to time

$\theta_1 = 0.02, \ \ \theta_1 = 0.01, \ \ \beta_1 = 0.7, \ \beta_2 = 0.7, \ \ \alpha_1 = 0.75, \ \alpha_2 = 0.76$

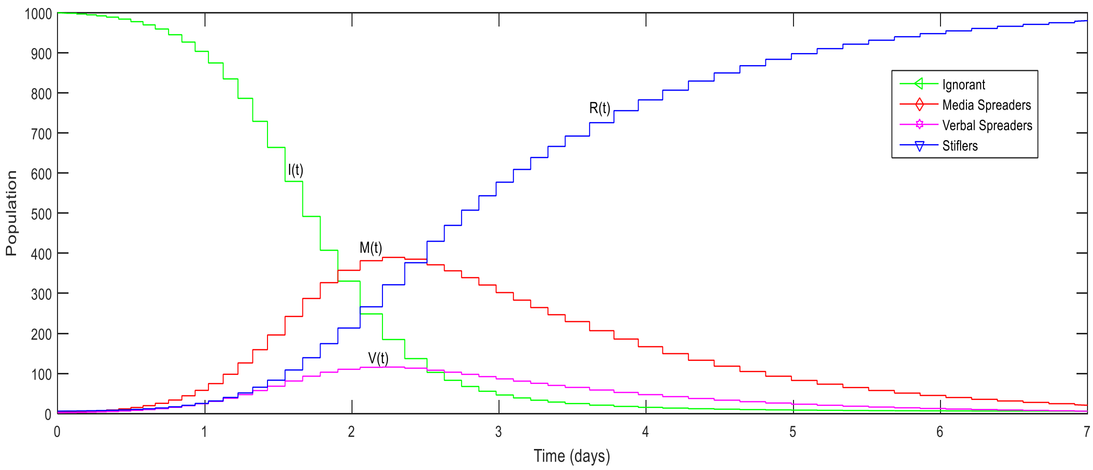

Figure 3: Variation of Ignorants, Spreaders and stiflers with respect to time

$\theta_1 = 0.02, \ \ \theta_1 = 0.01, \ \ \beta_1 = 0.6, \ \beta_2 = 0.7, \ \ \alpha_1 = 0.77, \ \alpha_2 = 0.78$

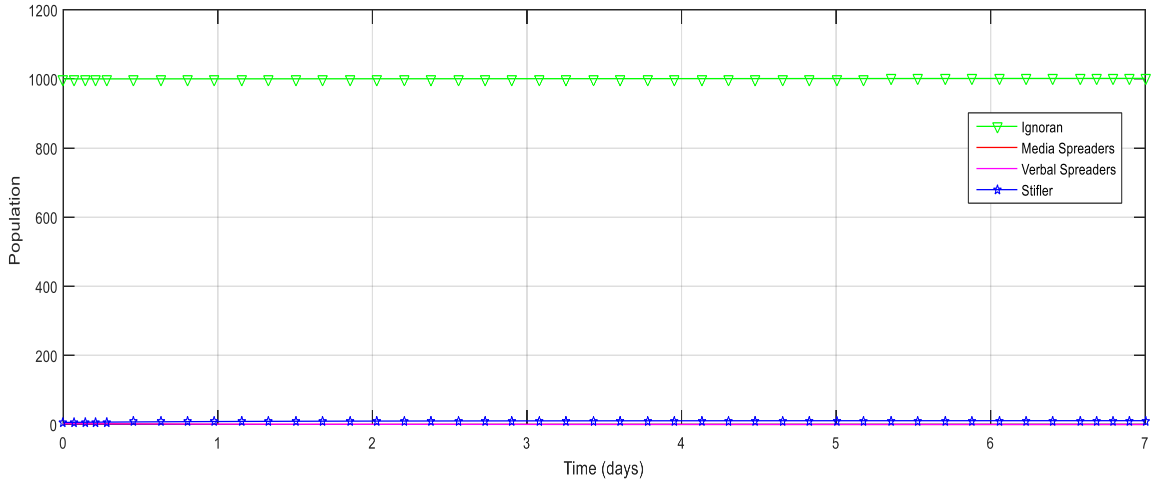

Figure 4: Variation of Ignorants, Spreaders and stiflers with respect to time

$\theta_1 = 0.02, \ \ \theta_1 = 0.01, \ \ \beta_1 = 0, \ \beta_2 = 0, \ \ \alpha_1 = 0.9, \ \alpha_2 = 0.95$

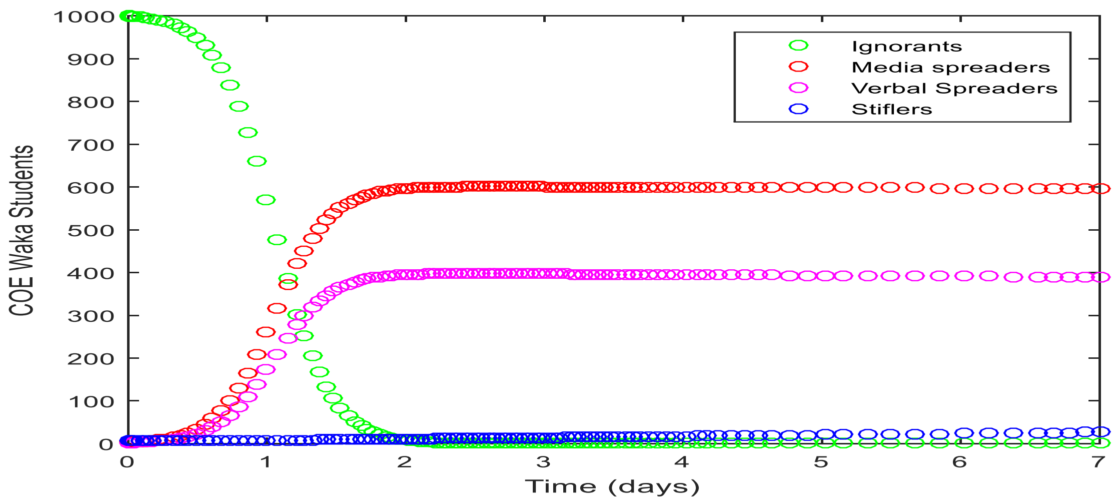

Figure 5: $R_o > 1$; the rumor persists at an "endemic" level within the first week with:

$\theta_1 = 0.02, \theta_2 = 0.01 \ \beta_1 = 0.8, \beta_2 = 0.5, \ \alpha_1 = 0.000001, \ \alpha_2 = 0.000001$

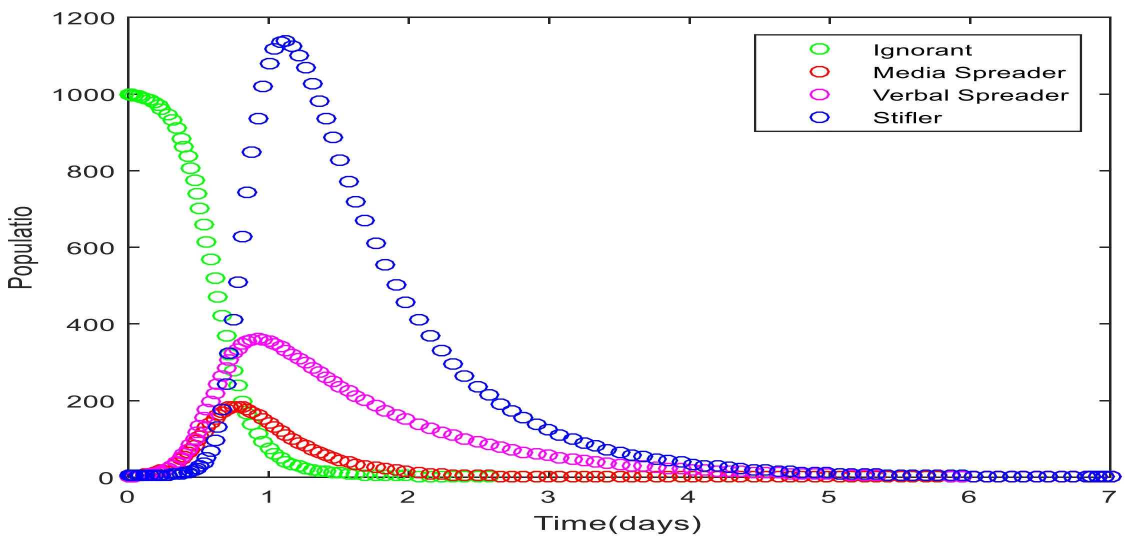

Figure 6: Decline of spreaders with respect to time: $\beta_1 = 0.1$ and $\beta_2 = 0.2$

From the similation, different classes of spreaders were plotted against time. The figure shows that at first, the number of spreaders increased to various maximum levels at different rates after which they returned to zero at different rate, while the number of the ignorant decreases as a result of increase in the class of spreaders (figure 1 - 3). The verbal spreaders' curved reach it peak level faster and also decay faster followed by the media spreaders. From this we can infer that rumor spreading have a life span which depends on the type of spreaders class. Most of the people that leave the spreader class move to the stifler class at the rate α_1 and α_2. We observed that reducing the contact rates between the ignorant and spreaders will curtail rumor (figure 1 – 4).

From the simulation with $R_o < 1$ (Figure 6), we can find that there is a sharp increase in the number of stiflers with further spreading of the rumor, and the number of stiflers reaches a peak and thereafter declines. In the whole process, the number of spreaders always reduces while the number of stifler always increases respectively (figure 1 – 3). Finally, the number of spreaders is zero and this leads to the termination of rumor spreading (figure 4). From the simulation with $R_o > 1$, we can find that the numbers of spreaders reaches a peak at first and remain constant spreading the rumor until it evades the entire population. Finally, the rumor persists at an "endemic" level (figure 5). Recall that the parameter $\alpha_1 > 0$ and $\alpha_2 > 0$ describes the psychological quality of the general public toward the spreaders. Though the basic reproduction number R_o does not depend on the αs explicitly, numerical simulations indicate that when the rumor is endemic, the steady state value $M^{\approx}$ and $V^{\approx}$ of the spreaders decreases as $\alpha_1 > 0$ and $\alpha_2 > 0$ increases. Based on the above, one can draw a conclusion that the parameter α_1 and α_2 describes the psychological quality of the general public with respect to the spreaders.

7. INNOVATION

The main innovation in this paper is the collective behavior caused by unknown disease rumors crisis in college of education Waka Biu was described as psychological effect with rumor spreading model.

8. CONCLUSION

In this paper, a nonlinear mathematical model for rumor spreading has been developed and analysed using epidemiological approach. In our study, we consider two classes of spreaders and determine the threshold which governs the dynamics of the system. The spreading of the rumor through media and verbal communication are mutually exclusive. Therefore the appropriate increase in the media spreader is conducive to the elimination of the verbal spreader and vice versa. At this point, we conclude that people pay much attention to crisis information/story, contribute in spreading the information/story and lose interest for the same information after some time. We recommend the following few pieces of advice to general public on how to fight rumors:

- ✓ Don't believe information coming from traditional media and new media;
- ✓ Check the sources from where the news came;
- ✓ Do not consider any source as a prior authoritative;
- ✓ Increase your own basic scientific knowledge;
- ✓ Always maintain a genuine skepticism and develop critical thinking.

ACKNOWLEDGEMENTS

The authors thank the provost COE Waka Biu, Dr. M. A. Audu, the director of research; Dr. G. Saljaba and Mal. Madu Lawan Ngulde for their useful contributions.

REFERENCES

[1] Zhao L, Wang J, Huang R (2015) Immunization against the spread of rumors in homogeneous Networks. PLOS ONE 10(5): e0124978. doi:10.1371/journal.pone. 0124978

[2] Zho, Laijun; Wang, Jiajia; Chen, Yucheng; Cheng, Jingjing; Cui, Hongxin. SIHR rumor spreading model in social networks. ln physica A: statistical Mechanics and its application, vol.391, no.7.pp.2444 – 2453,2012.

[3] Allport, G., and L. Postman (1947). The Psychology of Rumor, New York, Henry Holt.

[4] Rosnow, R.L. and Foster, E.K. Rumor and Gossip Reseach. Psychological Science Agenda. (April 2005) Vol 19, 1 – 2.

[5] Rabajante, J. and Umali, R.E.2011. Amathematical model of rumor propagation for disaster management. Journal of nature studies. 10(2): 61 – 70

[6] Bordia, P. and Difonzo, N. Problem solving in social interactions on the internet: Rumor as social cognition (2004). Soc. Psychol. Quart., 67 (1), 33-49.

[7] Abdullahi, M, Mohammed A, and Abbas Umar, F. Rumor Spreading Model: Vulnerability and its psycological effect in study of salt and water ebola virus cure rumor of August 2014 in Nigeria. Proceedings of 56th ISERD International Conference, Mecca, Saudi Arabia, 16th -17th December 2016, ISBN:978 – 93 – 86291 – 59 – 2.

[8] Jung, C.G. (1959). A Visionary Rumour, Journal of Analytical Psychology, 4 (1), 5-19; available online, doi:10.1111/j.1465-5922.1959.00005.x.

[9] Festinger, L. (1957). A theory of cognitive dissonance, Evanston, IL, Row, Peterson.

[10] Prasad, J. (1935). The psychology of rumour: A study relating to the great indian earthquake of 1934, Brit. J. Psychol., 26, 1-15.

[11] Newman M. Spread of epidemic disease on networks. Physical Review E.2002:66:01103/phys RevE.66.016128

[12] Delay DJ, Kendall DG. Epidemics and rumors. Nature.1964;204:1118.doi: 10.1038|2041118a0; PMID: 14243408

[13] Deley DJ, Kendall DG. Stochastic rumours. IMA journal of Applied Mathematics.1965; 1:42

[14] Musa, S. and Fori, M. (2019) mathematical model of the dynamics of rumor propagation. Journal of applied mathematics and physics, **7**, 1289 – 1303. https:doi.org/10.4236/ jamp. 2019.760888

[15] Rene, E and Marco, O. (2017) A deterministic mathematical model for the spread of two rumors.

[16] Nekovee M, Moreno Y, Biaconi G, Marseli M. Theory of rumor spreading in complex social networks. Physica A. 2007; 374:457 – 470. doi: 10.1016/j.physa. 2006. 07.017

[17] J. A. Heesterbeek, and K. Dietz, the concept R_o in epidemic theory. Statistica Neerlandica, 1996,50,89-110.

[18] Diekmann, O., Heesterbeek, J., and Roberts, M. (2009). The Construction of next-generation Matrices for Compartmental Epidemic Models. The royal society interface, 7,873 – 885.

[19] H.W.Hethcote, “The mathematics of infectious diseases,” *SIAM Review*, vol. 42, no. 4, pp. 599–653, 2000.